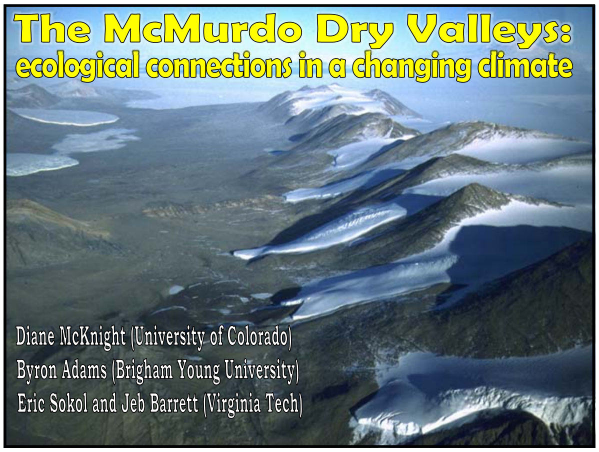
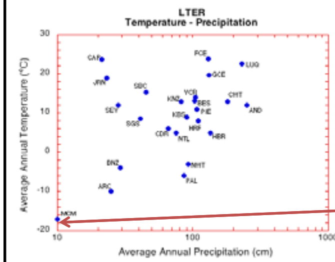


The McMurdo Dry Valleys: ecological connections in a changing climate

Diane McKnight (University of Colorado)
Byron Adams (Brigham Young University)
Eric Sokol and Jeb Barrett (Virginia Tech)

The MCM is the coldest and driest site in the LTER network



McMurdo Dry Valleys-Taylor Valley

McMurdo Dry Valley Averages and Extremes
(1985-2012)

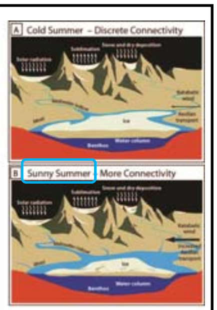
	C	F
Surface air temperature		
average mean annual	-17.9	-0.2
absolute maximum	9.9	49.8
absolute minimum	-47.7	-53.9
Degree days above freezing		
mean annual	21.9	21.9
Soil temperature at surface		
average mean annual	-17.6	0.3
absolute maximum	25.7	78.3
absolute minimum	-51.1	-60.0
Surface wind speed	**(ms^{-1})**	**(MPH)**
average mean annual	2.7	6.0
maximum	22.8	51.0
Precipitation	~ 4 cm per year (water equivalent)	
Sunshine	5 months of darkness	
Stream flow	**Lots to none at all!**	

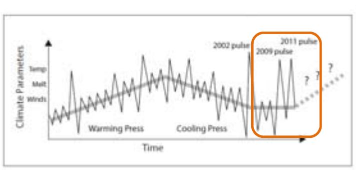
MCMLTER project: Interdisciplinary team

Linkages among ecosystem components: glaciers, soils, streams, and lakes

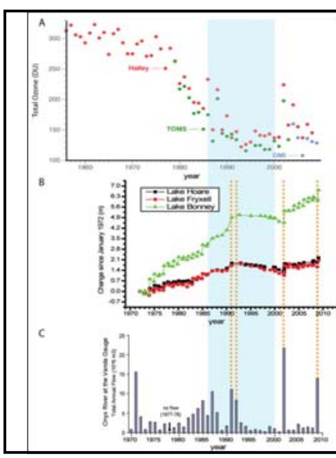
Post-doctoral fellows, research associates, collaborators and students

Conceptual framework: Amplified response of extreme ecosystems to disturbance associated with dynamic climate

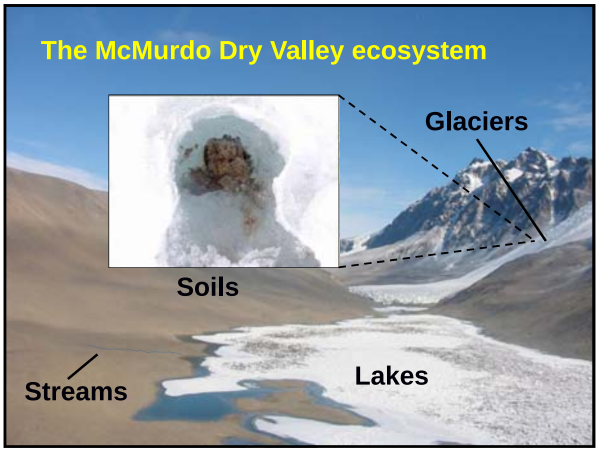


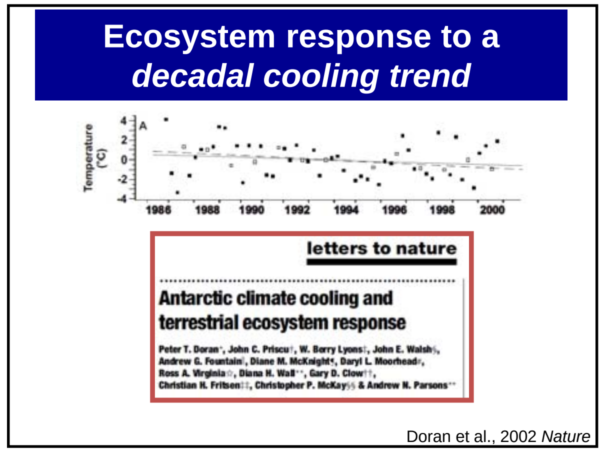


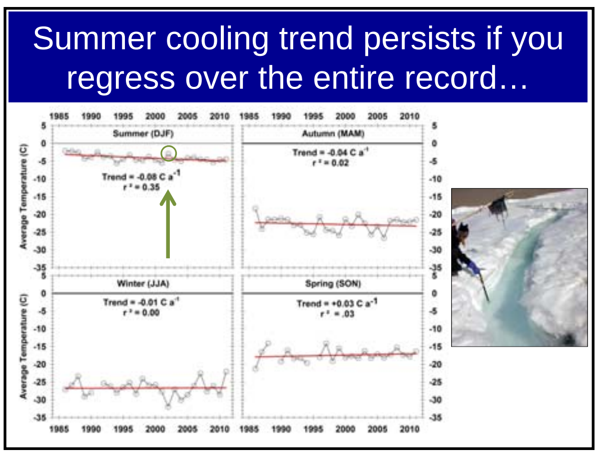
Overarching Hypothesis: Ecological response is driven by changing landscape connectivity

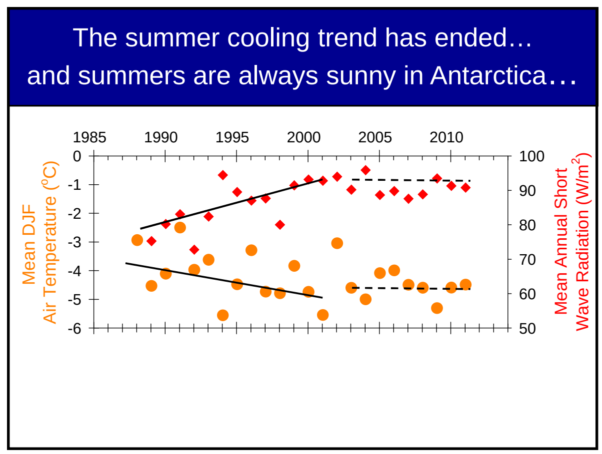


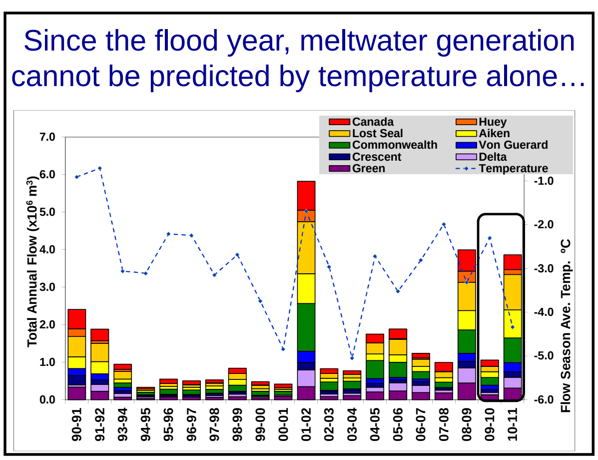
Cooling trend: interrupted by Floods during summers of high solar radiation and strong winds

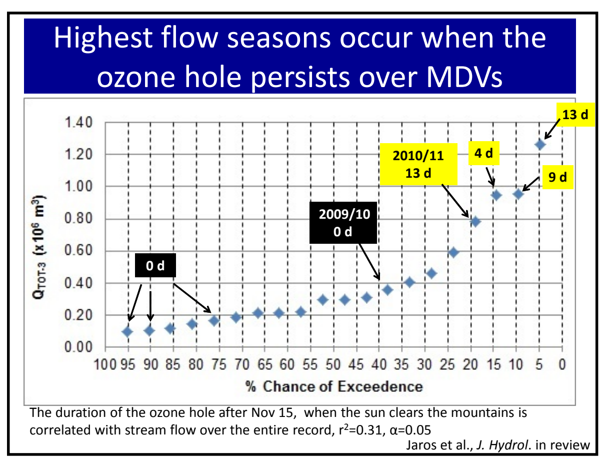

The McMurdo Dry Valley ecosystem
Glaciers
Soils
Streams
Lakes


Ecosystem response to a
decadal cooling trend
Temperature (°C)
1986 1988 1990 1992 1994 1996 1998 2000
letters to nature
Antarctic climate cooling and terrestrial ecosystem response
Doran et al., 2002 *Nature*

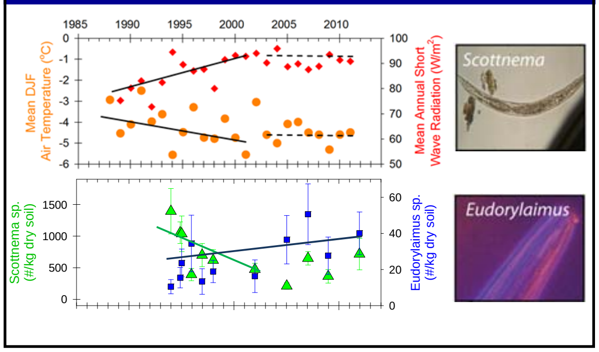

Summer cooling trend persists if you regress over the entire record…
Summer (DJF)
Trend = -0.08 C a-1
r² = 0.35
Autumn (MAM)
Trend = -0.04 C a-1
r² = 0.02
Winter (JJA)
Trend = -0.01 C a-1
r² = 0.00
Spring (SON)
Trend = +0.03 C a-1
r² = .03
Average Temperature (C)


The summer cooling trend has ended…
and summers are always sunny in Antarctica…
1985 1990 1995 2000 2005 2010
Mean DJF Air Temperature (°C)
Mean Annual Short Wave Radiation (W/m²)

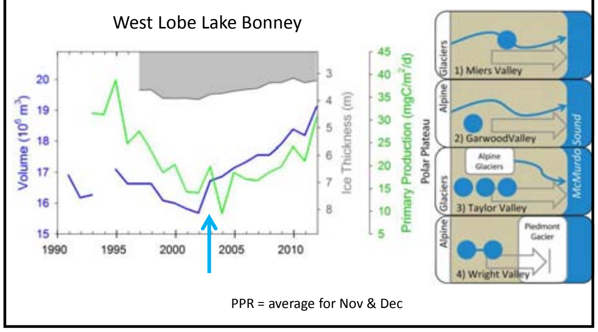

Since the flood year, meltwater generation cannot be predicted by temperature alone…
Canada
Lost Seal
Commonwealth
Crescent
Green
Huey
Aiken
Von Guerard
Delta
Temperature
Total Annual Flow (x10⁶ m³)
Flow Season Ave. Temp. °C
90-91 91-92 93-94 94-95 95-96 96-97 97-98 98-99 99-00 00-01 01-02 02-03 03-04 04-05 05-06 06-07 07-08 08-09 09-10 10-11


Highest flow seasons occur when the ozone hole persists over MDVs
QTOT-3 (x10⁶ m³)
% Chance of Exceedence
0 d
2009/10
0 d
2010/11
13 d
4 d
13 d
9 d
The duration of the ozone hole after Nov 15, when the sun clears the mountains is correlated with stream flow over the entire record, r²=0.31, α=0.05
Jaros et al., *J. Hydrol.* in review

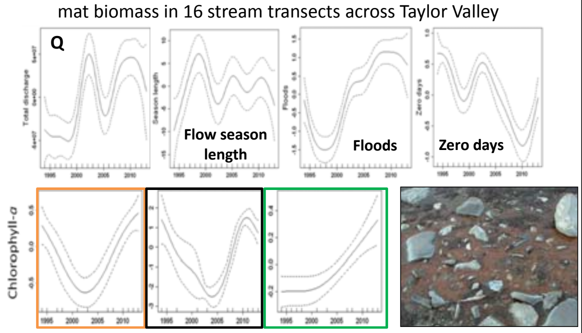
Soil invertebrates are no longer decreasing



Since 2002, lake volume and PPR are both increasing, ice covers are thinning



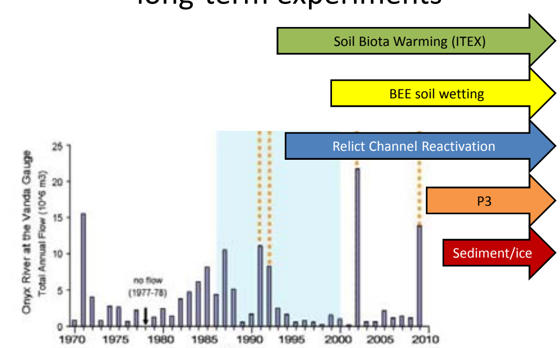
Additive mixed models to reveal drivers of long term changes in algal mat biomass in 16 stream transects across Taylor Valley



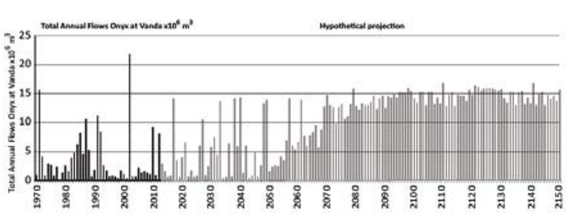
- Mat biomass decreased with a period of low flows and a "flood" summer.
- In-channel mats (orange and green) were more strongly correlated with hydrologic variables, (i.e., zero days), than marginal mats (black).

Kohler et al., *Ecosystems*, in revision

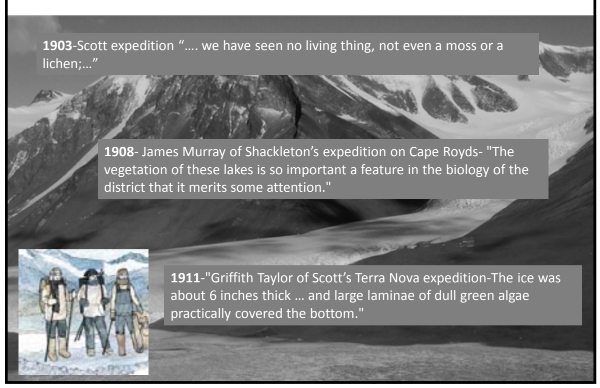
MCMLTER science discovery through long-term experiments



The implications of an ozone hole influence on the magnitude of the flow is that the 2001/02 event may be a millennial scale event, and may not represent the future under a warming climate.



Development of terrestrial ecology in the Heroic Era



Biodiversity: From the Heroic Era to today

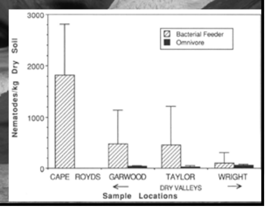
1969 – Horowitz et al., (1969) Sterile soil from Antarctica: organic analysis. Science 164: 1054-1056

The chemical results thus support the conclusion that the soil is actually sterile. This sterility, which is remarkable in itself, has significant implications for planetary exploration. It sug-

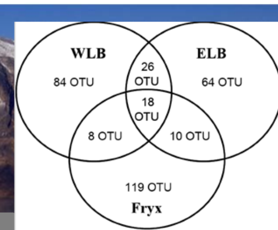
Circa 1987 – Nematodes, tardigrades and rotifers known to be present, but restricted to wet habitats

1990 – Nematodes, tardigrades and rotifers are **abundant** in many dry soils

Freckman DW, Virginia RA (1990) Nematode ecology of the McMurdo Dry Valley ecosystems. Antarctic Journal of the United States 25: 229-230



Biodiversity: From the Heroic Era to today



2005 –

- McMurdo Dry Valley Lakes **Microbial Observatory**
  - Diversity & distribution: Phylum-level clone libraries
  - Lakes Highly structured as a function of historical legacy

Biodiversity: From the Heroic Era to today

ELSEVIER

Soil Biology & Biochemistry 38 (2006) 3003–3018

Soil Biology & Biochemistry

www.elsevier.com/locate/soilbio

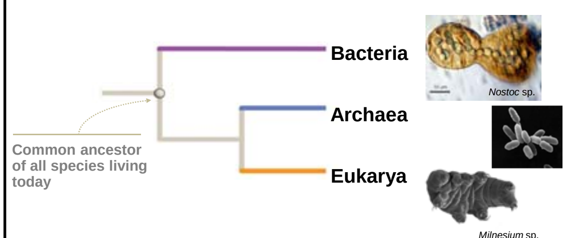
Diversity and distribution of Victoria Land biota

Byron J. Adams[a,*], Richard D. Bardgett[b], Edward Ayres[c], Diana H. Wall[c], Jackie Aislabie[d], Stuart Bamforth[e], Roberto Bargagli[f], Craig Cary[g], Paolo Cavacini[h], Laurie Connell[i], Peter Convey[j], Jack W. Fell[k], Francesco Frati[l], Ian D. Hogg[m], Kevin K. Newsham[j], Anthony O'Donnell[n], Nicholas Russell[o], Rodney D. Seppelt[p], Mark I. Stevens[q]

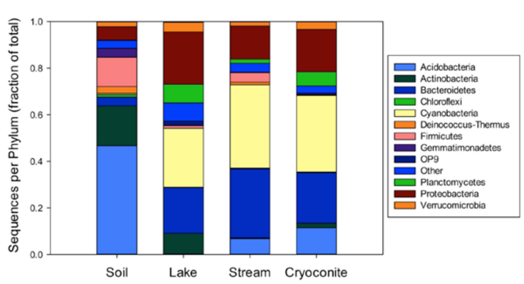
2006 –

- Microarthropods, nematodes, algae, mosses & lichens well-characterized (but highly localized)
- Community composition poorly characterized
- Prokaryotes, Fungal and Protist groups still poorly characterized

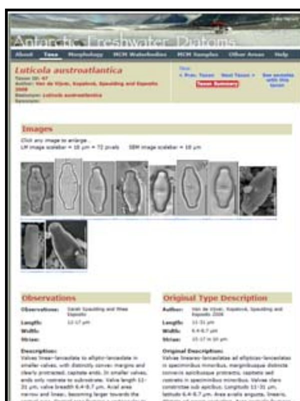
Biota of the McMurdo Dry Valleys *and* The Tree of Life



MCM Bacterial Diversity



- Diversity and endemism is higher than previously thought – highly structured by landscape unit
- Diversity is relatively low, ***but*** functional diversity in soils can be as high as temperate forests



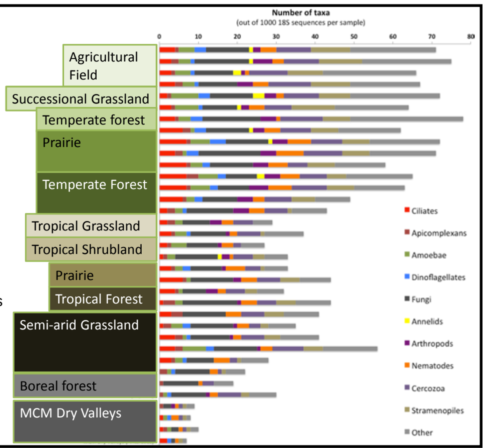
Antarctic Freshwater Diatoms: relational database and website with over 200 taxa

http://huey.colorado.edu/diatoms/about/index.php

Comparison of Eukaryotic soil diversity

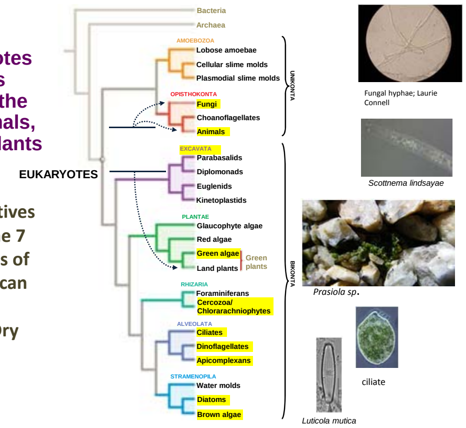
Number of taxa per sample based on taxonomic level (NCBI level 5)

Taxonomic units based on 97% sequence similarity



All eukaryotes are protists except for the fungi, animals, and land plants

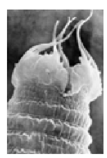
Representatives from 6 of the 7 major clades of Eukaryotes can be found in McMurdo Dry Valley soils



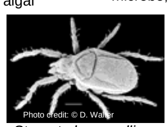
Dry Valley Beastiary

Philodina sp.
microbe, algal feeder

Acutuncus antarcticus
microbe, algal feeder



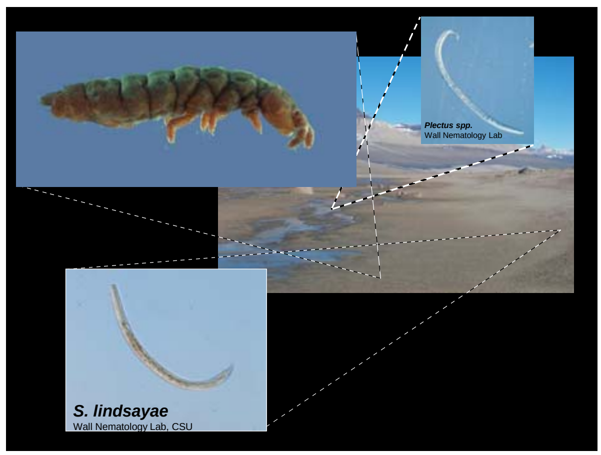
Scottnema lindsayae
microbivore



Stereotydeus mollis
Fungal feeder

Gomphiocephalus hodgsoni
Fungal feeder

Adapting to cold, dark, windy, dry…



Past studies show both dispersal and niche dynamics influence Dry Valley biodiversity patterns

- ***Nematodes*** – strong link to local habitat, widely dispersed

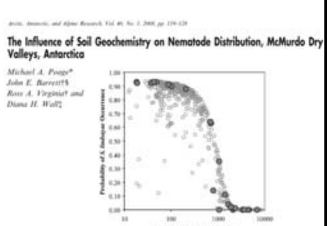
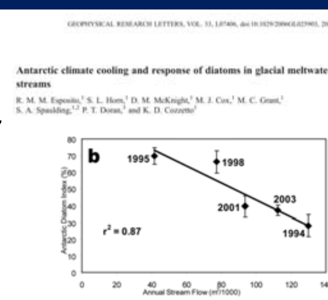


FIGURE 7. Probability of *S. lindsayae* occurrence plotted against soil conductivity from the >700 samples used in the logistic regression model (open circles) showing a steep salinity-driven survival gradient. Data from Bull Pass showing a similar response to soil salinity variation are superimposed on the larger data set (solid circles) and suggest that, within the observed ranges of soil moisture and total soil nitrogen, salinity exerts a first-order control over *S. lindsayae* habitat suitability on both a regional scale between valleys and on a smaller scale within the soil transect at Bull Pass.

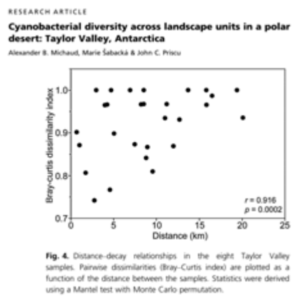
Past studies show both dispersal and niche dynamics influence Dry Valley biodiversity patterns

- ***Nematodes*** – strong link to local habitat, widely dispersed
- ***Diatoms in streams*** – colder, drier streams have more endemic "Antarctic" species



Past studies show both dispersal and niche dynamics influence Dry Valley biodiversity patterns

- *Nematodes* – strong link to local habitat, widely dispersed
- *Diatoms in streams* – colder, drier streams have more endemic "Antarctic" species
- ***Cyanobacteria*** **–** biogeography and strong local env. influence



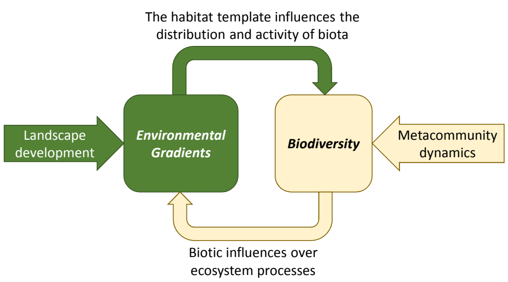
Biotic Influences Over Landscape

Organic matter primarily terrestrial origen

Organic matter primarily lake-derived

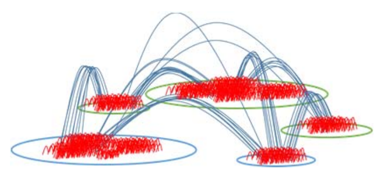
Burkins et al. 2000
Barrett et al. 2006
Bate 2007

The metacommunity concept is necessary to understand feedbacks between ecosystem processes and biodiversity patterns



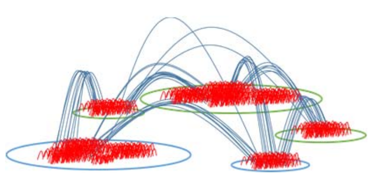
What is a metacommunity?

- Regional, *dispersal-based* dynamics
- Local, *niche-based* dynamics

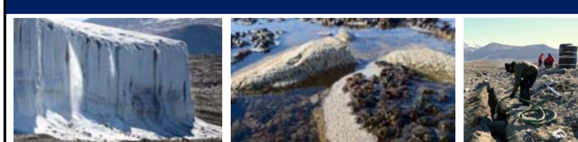


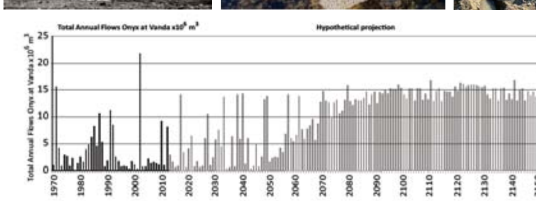
How does connectivity mediate the influence of local habitat over biodiversity?

- Regional, *dispersal-based* dynamics
- Local, *niche-based* dynamics



What are the consequences of increased ecosystem connectivity in the McMurdo Dry Valleys?

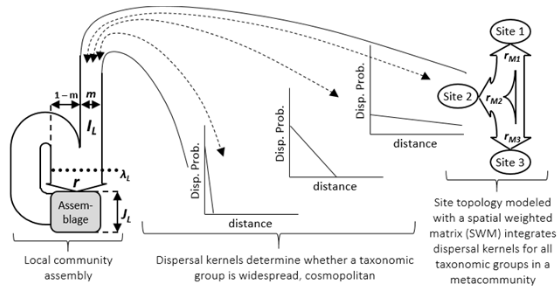




Why simulate metacommunities?

- ***Link process to pattern*** – e.g., what biodiversity patterns characterize systems dominated by niche- and/or dispersal-dynamics?
- ***Understand context*** – e.g., how might results be biased by study design, taxonomic resolution, ecosystem type?
- ***Forecast*** how biodiversity patterns change in response to a shift in metacommunity dynamics – *e.g., increased connectivity among landscape units*

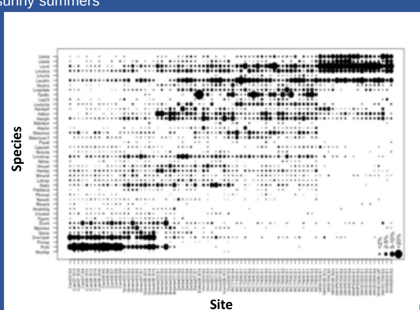
Metacommunity simulations: zero-sum, iterative lottery models (modified from Hubbell 2001, Gravel et al. 2006, and Sokol et al. 2011)



R package available at http://sites.google.com/site/metacommunitysimulation/

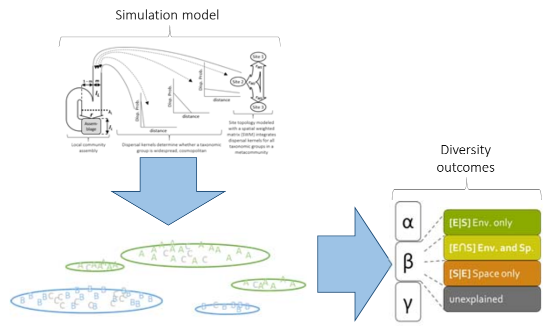
What does the metacommunity model represent?

= diatom taxa tolerant of desiccation, in streams that flow in warm sunny summers

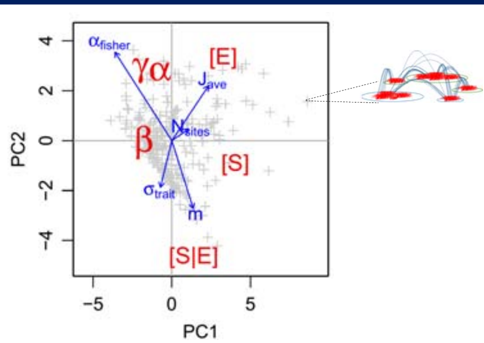


= diatom taxa dominant in streams that flow every summer, even during cold cloudy summers

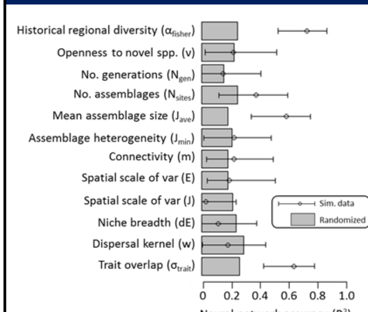
Metacommunity simulations: link scenarios with known *local* and *regional* dynamics to diversity outcomes

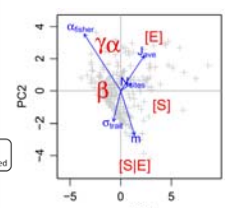


Simulated metacommunities serve as a template to understand biodiversity patterns – Morris type sensitivity analysis (Saltelli et al. 2000) of the metacommunity model (r = 20, N_{sims} = 260).

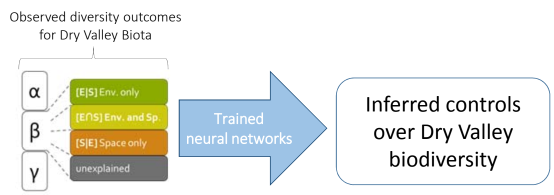


Simulated metacommunities are used to train and evaluate neural networks, which we then use to decode biodiversity patterns observed in nature.

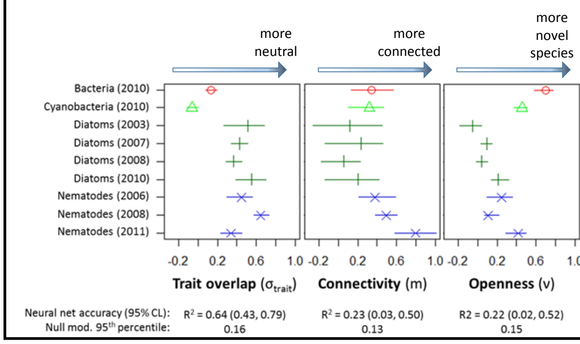




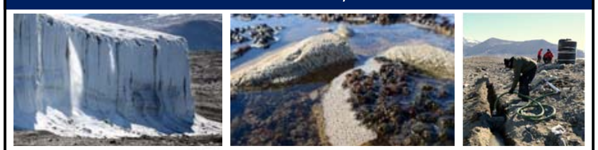
Use trained neural networks to decode biodiversity patterns observed for Dry Valley biota.

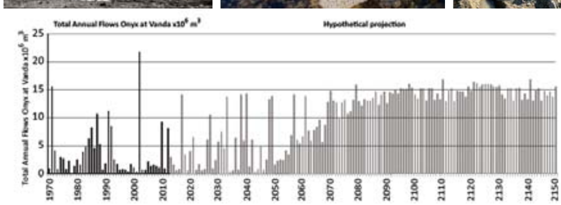


Nnets trained on metacommunity simulations suggest diatom biodiversity may be more sensitive to increased connectivity in the McMurdo Dry Valleys

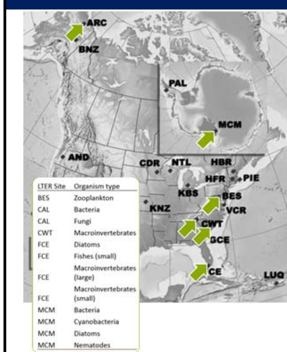


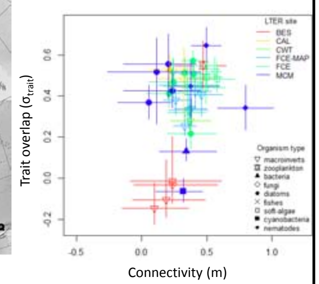
The perceived consequences of increased ecosystem connectivity in the McMurdo Dry Valleys will depend on how we measure biodiversity.



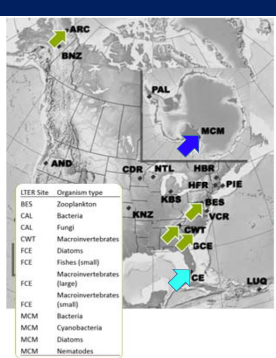


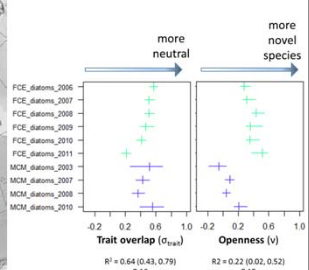
Synthesis of metacommunity datasets to understand context (i.e., How does ecosystem type, organism type, study design, and observational method influence conclusions?)





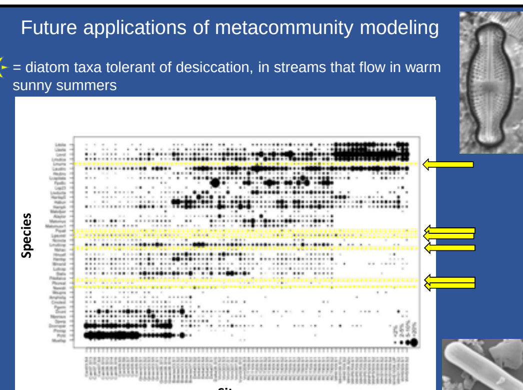
E.g., LTER Network perspective on the influence of hydroperiod on diatom metacommunity dynamics





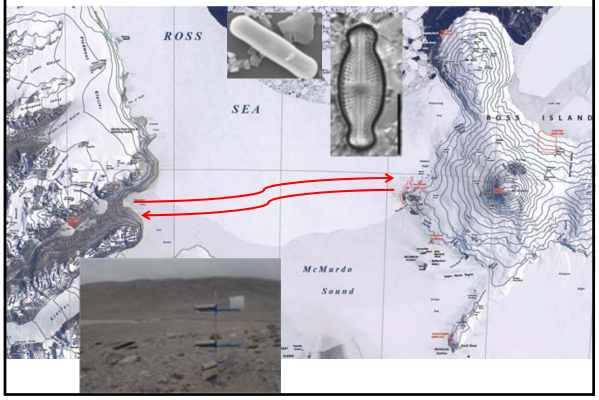
Future applications of metacommunity modeling

= diatom taxa tolerant of desiccation, in streams that flow in warm sunny summers



= diatom taxa dominant in streams that flow every summer, even during cold cloudy summers

Cape Royds: Connectivity of a Regional Metacommunity?



Miers Valley: High connectivty

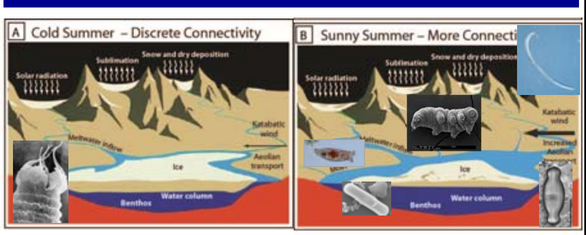
Enhanced hydro-climatic connectivity influences bio-diversity and nutrient cycling

Examples:
- Pulse Press Exp.
- F6
- Green Creek
- Wormheder Creek

Taylor Valley lake legacies: Connectivity among landscapes

Examples:
- Lake Bonney
- Lake Hoare

Climate warming in the McMurdo Dry Valley ecosystem will amplify connectivity among landscape units leading to enhanced coupling of nutrient cycles across landscapes, and increased biodiversity and productivity within the ecosystem.



THANK YOU!

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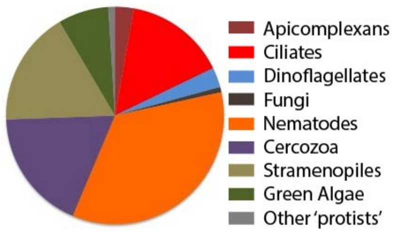
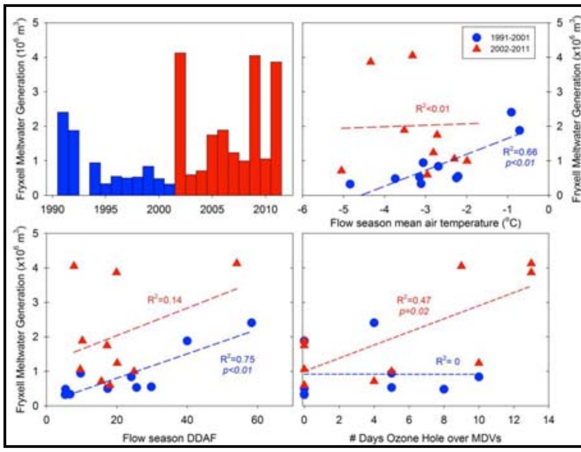
Abundance* and diversity of soil Eukaryotes



Abundance & diversity of eukaryote 18S rRNA from MCM Dry Valley soils (1000* amplicon gene reads)



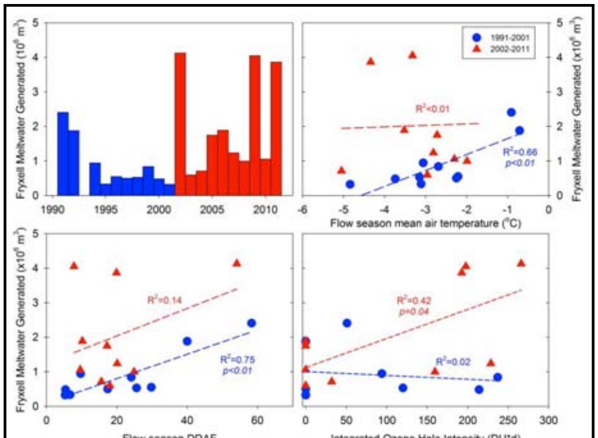
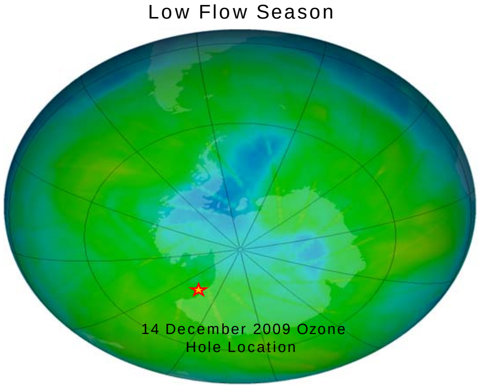


Table 6. Linear regression model results between flow characteristics and potential climatic drivers, divided into two periods: 1990-2001, and 2001-2011. Test results for significant relationships are listed with R2 and confidence level with regression slope in parentheses.

Significant R^2?		t_s	DDAF	DU_Duration	DU_Days	Albedo	Windy_Duration	Windy_Days
Flow	All	No	0.16, α=0.1 (33.4)	0.31, α=0.05 (146)	0.18, α=0.1 (5.19)	No	No	No
	1990-2001	0.65, α=0.01 (461)	0.75, α=0.01 (35.3)	No	No	No	No	0.45, α=0.1 (2.45)
	2001-2011	No	No	0.52, α=0.05 (184)	0.42, α=0.05 (8.16)	No	No	No

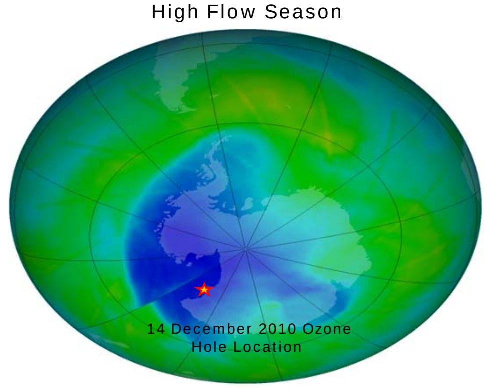
Jaros, C., D. M. McKnight, A. G. Fountain, T. Nylen, and M. N. Gooseff. *Journal of Hydrology*, in review.

December 2009 Ozone Hole Location
Low Flow Season



Source: ozonewatch.gsfc.nasa.gov

December 2010 Ozone Hole Location
High Flow Season



Source: ozonewatch.gsfc.nasa.gov